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System for Biological Sensor-Based Stress Detection Using the Bohm-Jacopini Algorithm

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Abstract: - Chronic stress has become a pervasive issue in modern society, particularly impacting professions like car driving. While mitigating stress entirely may not be feasible, exploring effective coping mechanisms is crucial. Although research on stress management is extensive, few studies have harnessed the power of modern technology to assess stress levels and simultaneously develop integrated management solutions.

Keywords: Biological Sensor-Based, Bohm-Jacopini, Stress Detection

I. INTRODUCTION

Stress has been dubbed the new health epidemic of the twenty-first century, with expenses to the US health care system alone reaching $300 billion. Numerous studies in the Philippines show that people in a variety of professions encounter stress related to their personal and professional lives, which could have major repercussions for their mental and physical health in the future. Empirical investigations have linked stress to a variety of mental diseases, which can reveal itself rather quickly after being exposed to stress. Additional research has shown that stress can have long-term effects on a person's physical health, including metabolic disorders, diabetes, cardiovascular illnesses, and endocrine dysfunction. An objective measurement of stress levels is missing from this literature, even though this research mostly focused on self-assessment to estimate stress levels and the results of extended stress exposure. Participant perception and subjectivity may lead to inaccurate results when stress levels are assessed by self-report.

However, given the way modern society is structured, it is hard to completely escape stress. Stress management is a method that is more practical. There are numerous resources available to aid in stress management. These include the application of cognitive and emotional therapy, which supports individuals in creating their own coping mechanisms, as well as the utilization of specific tailored therapies, such as smell therapy or music therapy. It has been demonstrated that music therapy has a real impact on the endocrine and Autonomous Nervous Systems (ANS). The ANS regulates bodily reactions that cannot be controlled consciously, such as blushing, sweating, heart rate, and others. The ANS appears to react to music by way of a parasympathetic route that causes a relaxing response. It has been shown that this mechanism shortens the time it takes the human body to recover from a stress response and return to normal functioning. The bulk of this research used relaxing music samples to trigger a relaxation response using either the participant's favorite music or the music associated with the ANS. A few examples of classical music were "Night on Bald Mountain" by Mussorgsky, "Minuet" by Boccherini, "Tchaikovsky Pathetique" by Tchaikovsky, and "Miserere" by Allegri. Participants in studies could also adjust the music's volume to a level that felt comfortable to them. In conclusion, the study on the impact of music on the ANS shows that classical music and participant favorites are the most calming musical samples. The participants should also be allowed to control their own volume levels to prevent the music from adding to their tension.

II. BACKGROUND OF THE STUDY

Recent technological advancements have greatly improved methods for measuring and controlling stress. The subjectivity of self-reporting is removed when stress levels are assessed objectively, leading to more accurate results. Numerous empirical studies have employed various sensors and programming to help individuals and other groups of people control their stress levels. Given that one aspect of modern living is an increased amount of time spent on work or leisure, this strategy appears to be very beneficial. Furthermore, the necessity of creating effective driver monitoring systems has been underscored by the rise in traffic accidents. Driver stress, which can impair cognitive and motor abilities, is a major factor contributing to these collisions. With these justifications in mind, using computer-assisted technology and sensory data to control stress seems plausible.

Galvanic Skin Response (GSR) has been shown in numerous studies to be a reliable stress indicator. GSR and

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electrodermal activity are based on anatomical concepts of stress reactions in humans. The Sympathetic Nervous System (SNS), one of the two major divisions of the ANS, regulates sweat gland activity, which influences GSR. The relationship between GSR and SNS is direct; when under stress, the SNS triggers a series of cascade reactions that also impact the sweet glands, which in turn affect GSR. Practically speaking, GSR Arduino-based models are not only straightforward to use and integrate with but also inexpensive and simple to maintain.

Photoplethysmogram (PPG) was employed in several research as a measure of stress. This approach uses the identical ANS response to stress, but instead of measuring the ANS response, pulse oximetry is used to assess the increase in blood flow to the skin. This measurement's underlying process is based on changes in artery volume that are tracked. PPG and GSR were frequently combined with other stress indicators in studies that employed them to detect stress.

III. SCOPE AND LIMITATION

The current study has a few drawbacks that can be found. First, it should be remembered that the quantity of cortisol receptors in the brain controls how well humans can manage their stress response. This variation can help some people manage their stress better while having negative effects on others. The study cannot take this confounding factor into account because the sample's capacity to manage physiologic stress will not be evaluated. A mean value indicator, a minimum and maximum stress level, and normal levels will be employed to measure stress levels in the sample to get around this restriction.

The quantity of subjects employed in the current study is a second constraint. This study will not be able to include the minimal number of 10 participants required to reduce the possibility of type I and type II errors (incorrect acceptance of the null hypothesis) due to logistical reasons. There are 25 samples overall available at the site of the study. The ideal sample required to minimize error will be determined using Slovin's formula sampling technique, however this also indicates that the results will only be generalizable to the sample in the population investigated, and to a lesser extent to a wider population.

Finally, the goal of this study is to ascertain whether PPG and GSR sensory data are useful in estimating levels of stress in the human body and whether music can shorten the time it takes for the body to recover from stress. This suggests that the study will not evaluate the effectiveness of the sensors or measure any additional stress indicators. Furthermore, the experiment's soundtrack will not be subjected to any customization or preference testing.

IV. GENERAL OBJECTIVE

This research aims to create an Arduino-based system for measuring and controlling the human stress response. To achieve the goal of this research, several objectives have been developed:
1. To develop a functioning stress assessment module that can collect data from car drivers.
2. To develop a functioning stress assessment module that can analyze stress data from car drivers.

V. STATEMENT OF THE PROBLEM

According to the research, there is a large amount of stress being felt by car drivers as they perform their task, which could have an impact on both physical and mental health. Although there are ways to control stress, it cannot be entirely eradicated. The use of technology to reduce stress has only lately started to be investigated. Since Filipino car drivers spend a lot of time on the road, this way of stress management may be more efficient and time-efficient than therapeutic techniques. It is suggested that stress levels in a sample of car drivers be measured using PPG and GSR monitoring as part of a stress reduction plan. Following the detection of stress levels, the device will play calming music for about 10 minutes to dampen the body's stress reaction through ANS control.

The planned investigation will serve as the foundation for the study's efforts to address the following issues:
1. How will the developed system for stress level assessment collect data on stress level indicators from car drivers?
2. How will the proposed system for stress level assessment analyze the collected input to trigger a stress reduction intervention?

VI. CONCEPTUAL FRAMEWORK

The current work aims to shorten the duration of the human body's stress reaction by modifying the ANS stress response. It is founded on the biological theory of stress. The conceptual framework for this inquiry will be grounded on Hans Selye's General Adaptation Syndrome (GAS) model from 1950. The simulation believes that the organism's usual condition is one of homeostasis. The body reacts biologically normally in this state in the

absence of an external stressor. According to this paradigm, stress results in three stages of an organism's response. When the body detects a stressor in the first step, the Critical Level starts. After this point, the body starts to adapt to stress by producing changes like heightened heart rates, elevated pulse rates, and increased sweat gland activity (Seaward, forthcoming 2018; Baker et al., 2019). During this time, known as the Resistance Phase (Appendix 1), the body develops stress responses (Baker et al., 2019). The body's response through adaptation, which occurs when the organism's coping mechanisms lessen the stressor, may be followed by the Exhaustion Phase (Appendix 2) or the Recovery Phase (Cunanan et al., 2018). When the body reaches the point of fatigue, the ANS starts to produce recurring stress symptoms, such as elevated heart rate, respiration, and perspiration, among other biological reactions that gradually deplete the organism's energy stores. This implies that throughout the monitor point, the body will resume to release presentations of stress markers from PPG and GSR sensors for the objectives of the current study.

Permanent health consequences are seen when the body is in an exhausted state for an extended length of time. The beginning of some diseases, such as gastro-duodenal ulcers and cardiovascular disorders (Kumar, 2021) have been predicted in some studies using this model.

The literature asserts that knowledge of the many stages of the stress reaction can be universally attained using GAS. Therefore, in approaching the creation of this study, this theoretical framework will be applied. The goal of RM is to trigger the rest reaction in the autonomic nervous system (ANS), which will lessen or eliminate the stress reactions that the body experiences during the endurance stage. This is seen in the image below. This intermediary action is intended to lessen the body's propensity to revert to its basic homeostatic state following stress. An example of the theoretical framework that GAS employed for this investigation can be seen in Appendix 1. The conceptual framework used to design this study is shown in Figure 1 below.
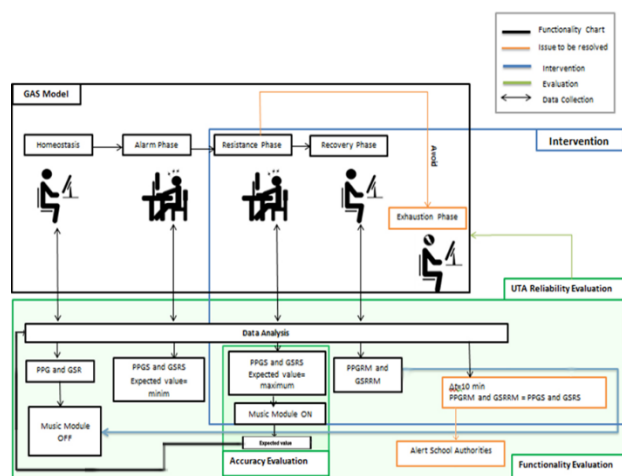

Figure 1 – Conceptual Framework

The framework illustrates that the suggested model may monitor stress levels in car drivers, give a therapy to reduce stress levels, and measure the efficacy of this treatment using the collected data. Both the fatigue phase and the recovery phase are feasible outcomes, according to the framework. If the individual is weary for an extended period, they may fall unwell. To prevent the ANS response that was engaged during the resistance phase and to encourage a return to equilibrium levels, the intervention aims to engage in the recovery phase when the body is exposed to calming music. When the documented readings, when listening to calming music are equal to the recorded values while under stress, an internal message should be sent to the driver's nearest family member to let them know the subjects' condition and location.

VII.   SIGNIFICANCE AND BENEFITS OF THE STUDY

This study aims to advance the body of knowledge regarding the effectiveness of PPG and GSR in identifying stress in humans. The goal of this study will be to develop a framework for measuring stress levels in motorists and to provide a stress-reduction strategy represented by calming music. The following will gain from this research:

1. The system will be useful to automakers, automotive technology developers, and regulators on road safety since it will help them become more aware of their customers' stress levels and act quickly to lower those levels and prevent weariness in drivers.

2. The proposed method will benefit motorists by reducing their stress levels and preventing them from entering

the fatigue phase of the General Adaptation Syndrome (GAS) theoretical model. This might make driving a little bit safer.

3. The proposed method can be improved upon by additional researchers, who can also examine the efficacy of the combined usage of PPG and GSR sensors for stress assessment. Other beneficiaries, such working people, could also benefit from the model's development.

4. Building upon this model, researchers can delve deeper into the efficacy of PPG and GSR sensors when used together for stress monitoring. Its adaptability allows for expansion to other groups, such as the workforce, paving the way for future advancements in stress detection.

VIII. REVIEW OF RELATED LITERATURE AND STUDIES

In various studies [1] GSR sensors were used to measure the effects of stress. Several stress measuring systems that either used GSR alone or in conjunction with other approaches were examined in this study using experimental designs. The sample must be pre-evaluated before the experiment under both normal and stressed conditions, according to some data [2], to obtain accurate measurements. This study found that the GSR fluctuation spans between 10 k and 10 M. As part of routine bodily actions, GSR is measured in micro-Siemens (S) and calculated using the subject's average results. A single measurement is insufficient; hence a mean value must be created for each individual [3]. The GSR values have been noted to be 7.5 Siemens and the phasic GSR rise time is 2.12 Siemens [4].

GSR has the potential to establish a real-time connection with stress parameters, which is crucial for determining its applicability as an accurate stress assessment tool [2]. This potential has been demonstrated in several research. This is due to the direct relationship between increased sweat production and greater skin conductance and lower resistance. By comparing it to other measures like respiration and heart rate, [1], [5] revealed this characteristic of GSR as early as that year. According to the calculations in this study, 100% accuracy was achieved for utilizing GSR to forecast stress levels, whereas 94.7% accuracy was achieved for less accurate predictions. Similar investigations conducted in 2021 by López, R., et al. produced conflicting findings and revealed that speech and heart rate indicators are stronger predictors of GSR than the latter. Using GSR and heart rate data, [1] found that stress prediction had a 99.5% accuracy rate. Individual measurements from the sample were taken in accordance with the experimental design of the study, and they were compared to both stress-free and stressful conditions [6].

Finally, this study supports that GSR is a precise indicator of the body's stress reaction [7]. However, measurements must be made for each person, and normal values must be noted and compared while under stress. Because each person's GSR varies personally, demonstrating that there are no appropriate norms, this technique is necessary. Another finding in this regard is that GSR may perform better when paired with other stress measurements, according to [1], [8].

PPG's efficacy as a stress indicator was the subject of additional experimental design research [9], [10]. To determine whether these measurements might accurately predict stress levels, PPG was paired with the electrocardiogram (ECG), pupillometry (PD), and PD [11], [12]. All three measures used a Fuzzy Support Vector Machine (FSVM) to import the data. The study found that when various sensory inputs are integrated, they can accurately reflect people's stress states. Utilizing sensors that keep track of changes in blood volume in the microvascular system makes it straightforward to get PPG data. Using an infrared source, the sensor measures the amount of infrared light that is not absorbed as wavelength hertz measurements (Hz) [13].

According to several research [13], PPG can be utilized to identify early indications of cardiovascular disease. As a result, for the purposes of this study, PPG measurements from each participant must be collected separately and averaged to prevent interference from variations in heart rate and other cardiovascular indicators [14].

IX. PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

In this section, the specified approach will be enumerated as an answer to the specific questions, and discussed how it was applied in this research in non-statistical way.
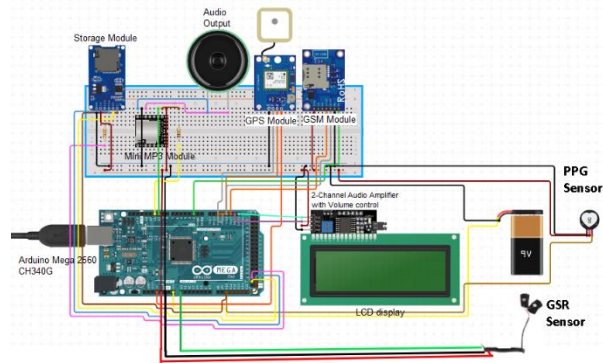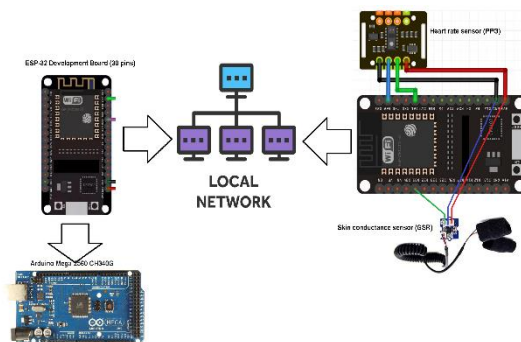
Figure 2 – Circuit Diagram Model

Figure 2a – Circuit Diagram Model of Wireless Sensors

The Arduino circuit will be developed based on ISC modelling, to which a music module will be attached. As shown in Figure 4, the circuit will consist of two (2) wearable sensors, an Arduino Mega 2560 CH340G microcontroller, a Wireless GSM GPRS module, a NEO 6M Ublox Flight controller GPS module, a 20x4 LCD L2C White on Blue, two (2) Micro SD cards module, two (2) Micro SD Cards, a SIM Card and an RTC module. Additionally, the design will require a 9V battery and a Basic Grove Shield with identical I/O pins as UNO R3. To measure PPG, a Pulse sensor AMPed is used, while for GSR a Seed Grove GSR sensor will be used (ISC).

Algorithm Discussion

A model for monitoring stress levels on an Arduino platform was created using the Böhm-Jacopini structures approach. This method was developed using the sequential execution, selection, and iteration of three fundamental control structures. During the subsequent implementation stage, also known as the execution, a set of tasks are carried out by the program in the particular sequence in which they are recorded. The sensors employed in this situation to assess stress and their associated coding sequences will record the participant outcomes. The major goal of the selection process in the second stage is to choose which logical statement (true or false) regulates which instruction will be performed in the third phase. In this instance, both sensors will show normal levels on the device, which represents the false statement.

Phase 3 of the process involves using iteration structures to repeatedly run similar statements in a loop up until preset requirements are satisfied. Currently, music is being played up till the first signs of homeostatic stress have been recorded (Talha Iqbal et al., 2022). The flowchart used to depict the algorithmic representations in this example uses GOTO (IF test=true THEN GOTO step X) form, where X denotes a specific algorithmic step—in this basis, executing song—and X is represented by these structures.

The algorithm is graphically depicted below. In this diagram, the different process steps are represented by rectangles. According to Panil Jain et al. (2020), the diamond figures indicate dividing out tasks that accept the system to execute one or more activities from a list of predetermined actions.
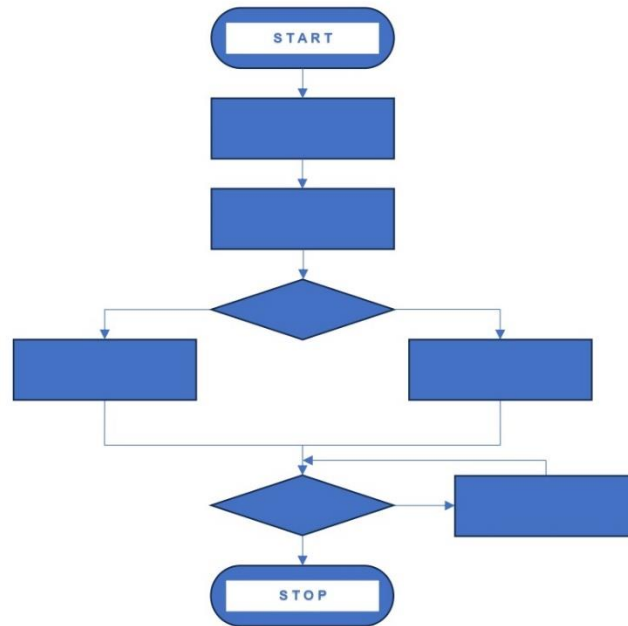
Figure 1 Böhm-Jacopini structures algorithm

The Böhm-Jacopini structures algorithm is a mathematical technique that can be used to analyze data from physiological sensors in order to detect stress. The algorithm works by identifying patterns in the data that are indicative of stress. For example, the algorithm could identify patterns in the driver's heart rate variability or skin conductance that suggest that they are feeling anxious or frustrated. It is a powerful tool that can be used to improve the accuracy of stress detection devices for car drivers. By using this algorithm, researchers can develop devices that are more sensitive to changes in the driver's physiological state, and that are better able to distinguish between stress and other states, such as fatigue or excitement.

Here are some of the specific benefits of using the Böhm-Jacopini structures algorithm in stress detection devices for car drivers:

Increased accuracy: The algorithm can help to improve the accuracy of stress detection by identifying patterns in the data that are more indicative of stress than traditional measures, such as heart rate variability.

Reduced false positives: The algorithm can help to reduce the number of false positives by distinguishing between stress and other states, such as fatigue or excitement.

Improved sensitivity: The algorithm can help to improve the sensitivity of stress detection by identifying subtle changes in the driver's physiological state that may not be detected by traditional measures.

Overall, the Böhm-Jacopini structures algorithm is a valuable tool that can be used to improve accuracy, reduce false positives, and improve the sensitivity of stress detection devices for car drivers. This algorithm has the potential to make a significant contribution to the development of safer and more reliable vehicles.

The model will be established on the physical input from subjects, and the PPG and GSR sensor will assess homeostatic levels (no stress condition noted as PPG and GSR) and stress levels (noted as PPGS and GSRS) in a small sample. We'll notice values that fall between the minimum and maximum. The audio system will be shut off at the mean of the minimum and highest readings taken under normal circumstances to prevent reading-related system faults. The lowest and greatest mean values (PPGS and GSRS) collected when under stress will activate the audio module. PPGRM and GSRRM, which measure the body's response to stress, will be measured again after the audio module has played for 10 minutes. The minimum and maximum meanings will be determined based on the music's 10-minute playing time. These figures will be compared to those that were recorded under usual conditions. The (Lee, Y., et al. 2018) suggested time setting can be studied in the initial small sample experiment. This will help determine whether the suggested period is realistic for the sample being analyzed.

The PPGRM and GSRRM readings are expected to be as near as possible to the values recorded under typical circumstances. The system will then start the music module until the PPGS and GSRS readings are detected once more. The audio module will thereafter be turned off. Appendix 6 displays the coding sequence that matches the proposed technique. The diagram below depicts the suggested flowchart algorithm for building the Arduino circuit.
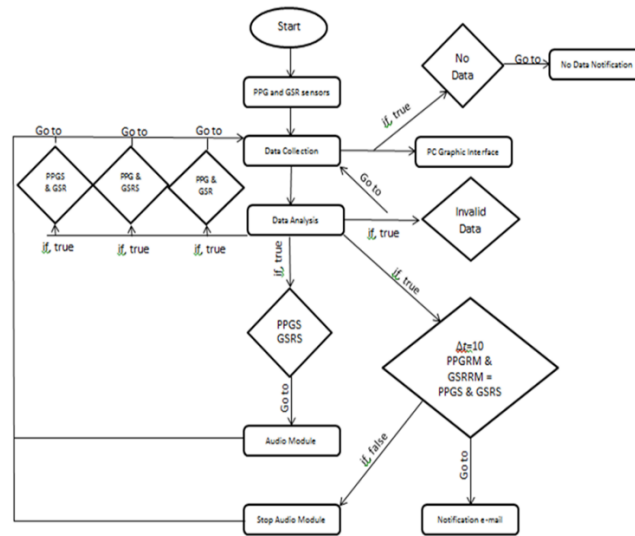
Figure 2 Proposed Algorithm

Algorithm for Stress Level Assessment

Input:
The PPG value array (n x 1) and GSR value array (n x 1) with 0 initial values where n is number of sectors to be pipelined.
   (This is one dimensional array)
 GSR_Value array (n x 1)
      GSR (g1, g2, g3… Gn)
   PPG_Value array (n x 1)
      PPG (p1, p2, p3… Pn)
 Denoising for both signal of simple low pass filter.
 y (n) = x (n) + x (n-1)

Preprocessing:
For GSR {} and PPG {}, calculate RMS (GSR {}) for average level of skin conductance voltage form and RMS (PPG {}) for average level of pulse voltage form.
 $x\_rms = \sqrt{1/n\,(⟦x\_1⟧^2 + ⟦x\_2⟧^2 + \cdots + ⟦x\_n⟧^2)}$
 $⟦RMS⟧\_Total = \sqrt{(⟦⟦RMS⟧\_1⟧^2 + ⟦⟦RMS⟧\_2⟧^2 + \cdots + ⟦⟦RMS⟧\_n⟧^2)}$

Update RmsGSR {} values when the next pipeline arrives.
Eliminate top 10 max values and 10 min values in GSR (g1, g2, g3… Gn) and
 PPG (p1, p2, p3… Pn)
   Set nn <- n/ 10;
{MaxGSR {a1, a2… A10} = {max {GSR (I x nn, (i+1) x nn)}
{MinGSR {a1, a2… A10} = {min {GSR (I x nn, (i+1) x nn)}
{MaxPPG {a1, a2… A10} = {max {PPG (I x nn, (i+1) x nn)}
{MinPPG {a1, a2… A10} = {min {PPG (I x nn, (i+1) x nn)}
The original number of arrays that come to the program is 500 for this device.
So, in GSR (g1, g2, g3… Gn),   n equals 500.
In each of these arrays, I also divide these 500 arrays into 10 parts.
nn <- n/ 10;   (Here nn = 500/10 = 50;
In each small array (nn = 50), I calculate maximum value and Min value.
Then 10 small arrays ------- 10 Min values and 10 Max values.
{MaxGSR {a1, a2… a10} = {max {GSR (I x nn, (i+1) x nn)}
{MinGSR {a1, a2… a10} = {min {GSR (I x nn, (i+1) x nn)}
{MaxPPG {a1, a2… a10} = {max {PPG (I x nn, (i+1) x nn)}
{MinPPG {a1, a2… a10} = {min {PPG (I x nn, (i+1) x nn)}

Repeat:

Initialize Rms (GSR { }), Rms (PPG { }), to eliminate top ten max values and min values and replace it as RMS value of each pipeline.

SUM (Max(GSR(a1, a2, …… , ann)) ☐ Rms(GSR{ }), I = 1, nn

SUM (Max (PPG (p1, p2… pnn)) ☐ Rms (PPG { }), I = 1, nn

Set the threshold conductance value GSR_Thr = Threshold_init

If RMS (GSR { }) > GSR_Thr Stress_level ☐ High

Else Stress_level ☐ Low

For PPG Sensor

Detection of R peak values for PPG sensor signal.

It shows the R-R intervals labeled A = (R-R) 1, B = (R-R) 2, C = (R-R) 3… (R-R) i represents the interval between two neighboring QRS peaks.

The RMSSD is looking for the successive difference between the intervals meaning:

A-B à(R-R)1 – (R-R)2

B-C à(R-R)2 – (R-R)3…and so forth

The RMSSD calculates to:

RMSSD =

Where N = number of RR interval terms

RMSSD =

In this equation RMSSD is just for measuring this variability.

If RMSSD (PPG (b1, b2 … bn)) > Thr

Stress_level ☐ High

Else Stress_level ☐ Low

Set the next pipelined arrays for PPG, GSR.

Final_Stress_Level = GSR_Stress *0.6 + PPG_Stress * 0.4

End repeat:

REFERENCES

[1] Gnecco, G., et al. (2018). Study and Analysis of Human Stress Detection using Galvanic Skin Response (GSR) Sensor in Wired and Wireless Environments. Research Journal of Pharmacy and Technology, 10(2), 545.

[2] Katsyri, J., et al. (2019). A Stress Sensor Based on Galvanic Skin Response (GSR) Controlled by ZigBee. Sensors, 12(12), 6075-6101.

[3] iMotions. (2018). What is GSR (galvanic skin response) and how does it work? iMotions.

[4] iWorks. Systems (2019). Galvanic Skin Response: an investigation into cheating (p. iWorks System Inc.

[5] Zaidi, S., & Collins, S. (2018). Orthostatic stress and area under the curve of photoplethysmography waveform. Biomedical Physics & Engineering Express, 2(4), 045006.

[6] Abbod, M., Chiou, Y., Yang, S., Fan, S., & Shieh, J. (2019). Developing a monitoring psychological stress index system via photoplethysmography. Artificial Life and Robotics, 16(3), 430-433.

[7] Prest, E., Felix, I., & Samuel, T. (2019). Stressors And Stress Management Amongst Undergraduates in The University of Benin. Lapai Journal of Management Science, 6(4), 473-483.

[8] Patel, S., Park, H., Bonato, P., Chan, L., & Rodgers, M. (2018). A review of wearable sensors and systems with application in rehabilitation. Journal Of Neuroengineering and Rehabilitation, 9(1), 21.

[9] Mert Sevil, Rashid, et al. 2019, Salai, M., Vassányi, I., & Kósa, I. (2019). Discrimination of simultaneous psychological and physical stressors using wristband biosignals.

[10] Salai, M., Vassányi, I., & Kósa, I. (2019). Stress Detection Using Low-Cost Heart Rate Sensors.

[11] Z. Ahmad (2020). Statistics: A Tool for Social Research. United Kingdom: Cengage Learning

[12] Bayoumy et al., (2021). Measurement of Heart Rate Using Photoplethysmography. Bangladesh University of Engineering and Technology.

[13] N. Mefraz Khan (2020). Detecting Stress During Real-World Driving Tasks Using Physiological Sensors. IEEE Transactions on Intelligent Transportation Systems, 6(2), 156-166.

[14] Nakashima, M., Ebihara, N., Nishijo, H., & Ohira, H. (2018). The effect of music on psychological and physiological stress. Journal of Human Environmental Studies, 11(1), 19-25.